

UNITED STATES PATENT APPLICATION

FOR

Method And Apparatus For Video Decoding On A Multiprocessor System

Inventors: Boon-Lock Yeo
Valery Kuriakin

Prepared By:
BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN
12400 Wilshire Boulevard
Seventh Floor
Los Angeles, California 90025-1026
(408) 720-8598

Attorney's Docket No.: 042390.P7940

"Express Mail" mailing label number: EL 431 890 855 US

Date of Deposit: December 22, 1999

I hereby certify that I am causing this paper or fee to be deposited with the United States Postal Service "Express Mail Post Office to Addressee" service on the date indicated above and that this paper or fee has been addressed to the Assistant Commissioner for Patents, Washington, D. C. 20231

Lisa Kaiser

(Typed or printed name of person mailing paper or fee)

(Signature of person mailing paper or fee) *Lisa Kaiser*

(Date signed) 12/22/99

5 METHOD AND APPARATUS FOR VIDEO DECODING ON A
 MULTIPROCESSOR SYSTEM

FIELD OF THE INVENTION

 The present invention relates computers and multimedia
10 processing, and, in particular, to the decoding compressed video on a
 multiprocessor system.

BACKGROUND OF THE INVENTION

15 Recent advances in computer technology have placed video
 applications within the reach of more common applications. For example,
 high Definition Television, Broadcast satellite Service, Cable TV
 distribution on optical networks, Electron Cinema, Interactive Storage
 Media, Multimedia Mailing, Networked Data base Services, corporate
20 Internet training and conferencing, Remote Video Surveillance and others
 are now becoming practical video applications.

 The large amounts of data needed to make video available in all
 these cases has lead to the adoption of Moving Picture Experts Group 1
25 (MPEG) and MPEG-2 standards for motion video compression and
 decompression. These standards significantly reduce bandwidth and
 storage space requirements. As a result, MPEG-1 and MPEG-2 are used in
 many video applications and are continuing to become more popular.

5 However, one feature limiting widespread use of the MPEG
standard is its computational complexity. Video encoding and decoding
under MPEG is expensive, often too costly for single processors to achieve
real-time performance in software for displays of acceptable resolution
and size. The computational demands grow as users desire higher quality
10 video.

 Encoding is more expensive than decoding, but can typically be
done offline and, therefore, may not need to be done in real-time.
Decoding, however, typically requires real-time performance.

5 SUMMARY OF THE INVENTION

10 The present invention provides a method and apparatus for decoding compressed video. The method includes reading a stream of compressed video into a memory. The video includes multiple pictures, with each picture having one or more independent elements. Thereafter, assigning, via a first processor of a group of processors sharing the memory, at least one independent element per processor to be decoded by the processors in parallel; and decoding the independent elements of the
15 video stream in parallel.

5 **BRIEF DESCRIPTION OF THE DRAWINGS**

Figure 1 illustrates the hierarchy of layers in an MPEG bitstream.

Figure 2 illustrates a block diagram of encoding and decoding
10 video data, according to one embodiment.

Figure 3 illustrates a block diagram of a picture slice structure.

Figure 4 illustrates a flow diagram describing the steps of decoding
15 video data with multiple processors in parallel, according to one
embodiment.

Figure 5 illustrates a multiprocessor computer system having a
computer readable medium with instructions stored thereon according to
20 one embodiment.

5 DETAILED DESCRIPTION

A method and apparatus for decoding compressed video on a multiprocessor system is disclosed. In the following description, for purposes of explanation, specific nomenclature is set forth to provide a thorough understanding of the present invention. However, it will be
10 apparent to one skilled in the art that these specific details are not required in order to practice the present invention. For example, although the embodiments discussed below describe the present invention being used to decode video data encoded in accordance with the MPEG standard, alternative video encoding/decoding standards could be used
15 without departing from the present invention.

MPEG Decoding

In its general form, an MPEG system stream is made up of two
20 layers: the system layer contains timing and other information needed to demultiplex the audio and video streams and to synchronize audio and video during playback; and, the compression layer which includes the audio and video data streams.

One embodiment of the hierarchy of layers in an MPEG bitstream
25 is arranged in the following order, as illustrated in Figure 1: Sequence, Group of Pictures (GOP), Picture Slice, Macroblock, and Block. The different parts of the stream are marked with unique, byte-aligned codes

5 called startcodes. These startcodes are used both to identify certain parts
of the stream and to allow random access into the video stream.

10 The highest level in the layering is the sequence level. A sequence
is made up of groups of pictures (GOPs). Each GOP is a grouping of a
number of adjacent pictures. One purpose in creating such an identifiable
grouping is to provide a point of random access into the video stream for
play control functions (fast forward, reverse, etc.).

15 Within each GOP are a number of pictures. In MPEG-2 interlaced
video is supported so each picture corresponds to either a frame (for
progressive or interlaced video streams) or a field (for interlaced video
streams) in the original stream.

20 Pictures are further subdivided into slices, each of which defines a
fragment of a row in the picture. Slices comprise a series of macroblocks,
which in one embodiment are 16x16 pixel groups containing the
luminance and chrominance data for those pixels in the decoded picture.

25 Macroblocks are divided into blocks. A block in one embodiment
is an 8x8-pixel group that further describes the luminance or chrominance
for that group of pixels. Blocks are the basic unit of data at which the
decoder processes the encoded video stream. Macroblocks and blocks do

- 5 not have startcodes associated with them; their boundaries are discovered implicitly while decoding.

Encoding

As described above, the block is the basic unit of data processing.

- 10 As illustrated in Figure 2, in one embodiment for each block of data in the video sequence, the encoder typically performs following five steps to produce an encoded block: motion estimation, discrete cosine transform (DCT), quantization, and run-length and Huffman coding.

- 15 In the first stage, motion estimation, the encoder tries to take advantage of temporal redundancies among pictures. The next four stages of the encoder take advantage of spatial correlation in compressing the video sequence. The result of performing these five encoding stages on all blocks in a video-sequence is an MPEG encoded video stream. A
20 stream may be encoded once and then transmitted across a transmission media and/or stored as needed. However, decoding is typically necessary each time the stream is viewed.

Decoding

- 25 The decoding process for an MPEG encoded stream typically performs the five encoding stages in reverse order. First Huffman and run-length decoding are applied to generate the quantized block. Then inverse quantization is performed to obtain the block's frequency

5 spectrum. From this, the inverse discrete cosine transform is taken. Then, if necessary, motion compensation may be used to generate the final macroblock of data from the prediction error, motion vectors, and reference picture.

10 A significant difference between the encoding and decoding processes is that in the former, much time is spent in motion estimation as it is necessary to search for the most similar macroblock in the reference picture(s), whereas in the latter, motion vectors are already available, which makes motion compensation much cheaper than motion estimation.

15

Decoding Video Data with Multiple Processors in Parallel

In order to increase the speed of decoding MPEG video data to provide the video data for more applications, one embodiment provides
20 parallel decoding of the video data among multiple processors in a single system, sharing a memory. In particular, in one embodiment, the workload of decoding the video data is distributed among the set of processors at the slice level. In alternative embodiments, the workload of decoding the video data could be distributed among the set of processors
25 at a level other than the slice level, without departing from the present invention.

5 In particular, as defined by the standard, a slice in MPEG is a series of an arbitrary number of macroblocks within one row of the picture.

Figure 3 illustrates a general slice structure. Each slice contains at least one macroblock, and consecutive slices may not overlap. Slices occur in the bitstream in the order in which they are encountered, starting at the upper-left of the picture and proceeding by raster-scan order from left to right and top to bottom. However, slices do not need to maintain the same structure from picture to picture: there may be different numbers of slices and/or different slice sizes.

15 Figure 4 is a flow diagram describing the steps of decoding the video data among multiple processors in parallel, according to one embodiment. In step 402 a first processor executing a first process, scans/reads a video sequence into memory from a disk or some other source of compressed video.

20 In step 404, the first processor further reads the video sequence to identify slice startcodes to identify the beginning of slices within the video sequence. In step 406, the first processor further reads the macroblocks within each slice to estimate the workload associated with decoding a respective slice.

25 In step 408, the first processor assigns one or more slices to be decoded, to each processor within a group of processors included in a

5 system. In one embodiment, the slices are assigned to the different
processors in a manner to spread the workload evenly among the
processors. For example, if a first slice includes many macroblocks, it
presumably will take longer to decode. Therefore, a second processor
would be assigned fewer slices to decode because at least one slice
10 presumably will take longer to decode. Subsequent adjacent slices may
include significantly less macroblocks. Therefore, a third processor, may
be assigned more slices to decode, with each slice containing less
macroblocks. In the end, each of the processors, in one embodiment, is to
receive a comparable workload of slices to decode.

15
In step 410, the first processor writes in a shared memory, the first
and last assigned slices as local variables for each of the processors that
are provided to decode the slices. For example, if the second processor is
to decode slices 1-3, a third processor to decode slices 4-8, and a fourth
20 processor decode slices 9-12, the slice numbers are written in memory as
local variables for each of the respective processors. One benefit to
assigning the slices by identifying the slices as local variables for the
respective processors, as opposed to providing the slices in a jointly
accessible task/slice queue, is the avoidance of conflicts between
25 processors in accessing the queue to identify slices to be decoded.

For example, in the case of using a slice queue, once a processor is
done decoding a slice it would return to the queue to determine the next

5 slice to be decoded. In addition, the processor would also increment a
pointer identifying the next slice to be decoded so that the next time a
processor accesses the queue it will receive the subsequent slice to be
decoded. Moreover, the queue would be accessed fairly frequent. As a
10 frequent. However, by assigning the slices to be decoded as local
variables for each of the respective processors, conflicts between the
processors in accessing the memory is significantly decreased.

In step 412, the respective processors read their respective local
15 variables to determine which slices are to be decoded, and thereafter read
the slices from memory and decode the slices in accordance with the
decoding procedures discussed above. In one embodiment, the processor
that assigns the slices to be decoded also assigns to it's self, one or more
slices to be decoded, which the processor thereafter proceeds to decode
20 along with the other processors. Moreover, in one embodiment, the
respective processors perform the steps of decoding the slices by
executing software routines stored in memory, provided for performing
the decoding steps as discussed above (e.g., Huffman decoding, Run
length decoding, etc.).

25

Thereafter, the first processor continues to scan/read in the video
data and assign contiguous slices to the processors for decoding, for the
desired quantity of video that is to be decoded. Furthermore, the method

5 of decoding the video data by distributing the workload among multiple processors, as described above, can be performed in real-time.

Figure 5 illustrates a system that is capable of decoding multiple slices in parallel with multiple processors, according to one embodiment.

10 As illustrated, the system includes multiple processors sharing a memory (e.g., Symmetric Multiple Processor architecture). In an alternative embodiment, the multiple processors could access separate memories, rather than sharing the same memory, without departing from the present invention.

15 Moreover, as shown in the memory of the system in Figure 5, the unit of logic to perform the method of decoding the video data through the use of multiple processors in parallel, as described above, could be provided a set of computer instructions to be executed by one or more of
20 the processors. In addition, the logic to perform the steps of decoding the video data could also be provided/stored in memory as a set of computer instructions (e.g. MPEG decoder). The instructions to perform the methods as described above could alternatively be stored on other forms of computer/machine readable medium, including magnetic and optical
25 disks. For example, method of the present invention can be stored on computer/machine readable mediums, such as magnetic disks or optical

5 disks, that are accessible via a disk drive (or computer-readable medium drive), such as the disk drive shown in Figure 5.

Alternatively, the logic to perform the methods as discussed above, including the method of decoding video data via multiple processors in parallel, could be implemented in additional computer and/or machine
10 readable mediums, such as discrete hardware components such as large-scale integrated circuits (LSI's), application-specific integrated circuits (ASIC's), firmware such as electrically erasable programmable read-only memory (EEPROM's); and, electrical, optical, acoustical or other forms of
15 propagated signals (e.g., carrier waves, infrared signals, digital signals, etc.).